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GUIDE TO THE GEOLOGY OF
PFEIFFER BIG SUR STATE PARK
MONTEREY COUNTY, CALIFORNIA

By GORDON B. OAKESHOTT

GUIDE TO THE GEOLOGY OF PFEIFFER BIG SUR STATE PARK, MONTEREY COUNTY, CALIFORNIA*

By Gordon B. Oakeshott †

OUTLINE OF REPORT

Illustrations

ABSTRACT

Pfeiffer Big Sur State Park includes an irregularly shaped area of about 1 square mile in the lower valley of the Big Sur River which rises in the Santa Lucia Mountains and empties into the ocean a short distance south of Point Sur. The Park is crossed by Highway 1 about 27 miles south of Carmel in Monterey County.

The Santa Lucia Mountains reach a maximum elevation of about 3500 feet in the vicinity of the Park. The mountains have a broad summit area of subdued mature relief, but drop off very abruptly to form steep cliffs at the margin of the sea. The Big Sur River has cut a steep-sided narrow gorge in the higher eastern part of the Park and flows over a gentle grade in a broader valley along the Sur fault zone through the camp area. Repeated uplift in late geologic time has caused the river to leave a series of gravel-covered benches or terraces at several levels near its course.

The central part of the range is made up of the very old crystalline rocks of the Sur series which have been intruded by later Santa Lucia granite. This group of rocks has been thrust southwestward and upward over Franciscan sandstone and shale along the Sur-Sur Hill fault zone. The Sur fault and Sur Hill fault in the State Park are separated by a sliver of Santa Margarita sandstone a few hundred feet across. Movement along this major thrust fault zone probably began as early as upper Miocene time and ceased by late Pleistocene time.

Present topography is the result of repeated near-vertical uplift and erosion in late Quaternary time.

INTRODUCTION

Purpose of Report. The vacationing public is visiting our State parks in ever-increasing numbers, coming not only from California but from out-of-state by the thousands. The greatest season of influx is the summer when the Big Sur, like other parks, is filled to capacity but off-season visitors are becoming more common. Some of these visitors are occupied primarily with the purely recreational features at Pfeiffer Big Sur State Park, but many are also keenly interested in the unrivalled natural features—the plants and trees, the animal life, land forms, and rock formations. Park naturalists, in conducting their nature-study programs and trips, are faced with pointed and specific questions which deserve carefully considered and scientifically sound answers. This report is the result of a study made by the State Division of Mines, at the request of the State Division of Beaches and Parks—both in the Department of Natural Resources—for the purpose of giving a background of information on the geologic features of the Park.

Geologic Study of the Park Area. Few areas of the size of Big Sur State Park expose evidence of such a striking geologic history. Steep and high coastal cliffs and terraces, visible from Highway 1, the high crest of the Santa Lucia Mountains with its subdued summit relief, and the spectacularly rugged gorge of the Big Sur River giving way to the quiet flat-floored, tree-covered valley in the Park area focus attention on the possible geologic interpretation of such a landscape.

The geologist, who deals with land forms, rocks, and the history of their formation, recognizes the great length of time required in development of the features of the land surface as seen today. His concept of time is in terms of thousands, millions, and even hundreds of millions of years. When this fundamental concept is recognized, little further stretch of the imagination is needed to visualize, for example, the Big Sur River deepening its channel across the Sur gneiss by the constant erosive action of running water carrying rock fragments to form the present steep and narrow gorge. Even a downward cutting of a tenth of an inch a year would form a deep channel in a half million years, *if the process were uninterrupted.* Actually, such processes are often interrupted, particularly by crustal deformation caused by little-known forces within the outer layers of the earth's crust. Three types of crustal deformation may be observed in Big Sur: broad uplift accompanied by gentle tilting of the earth's surface, folding of rock formations, and breaking and relative displacement of rock formations along faults.

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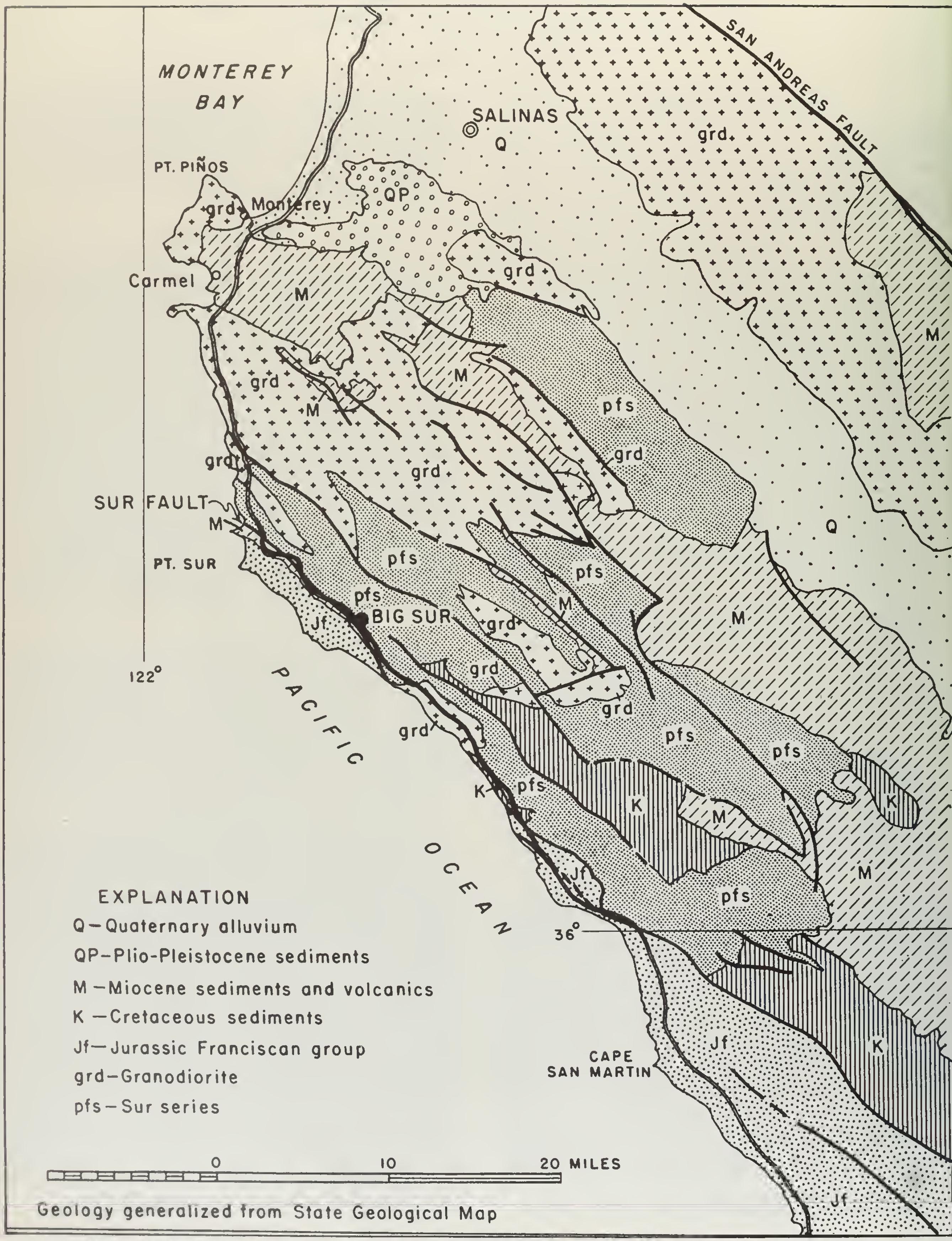
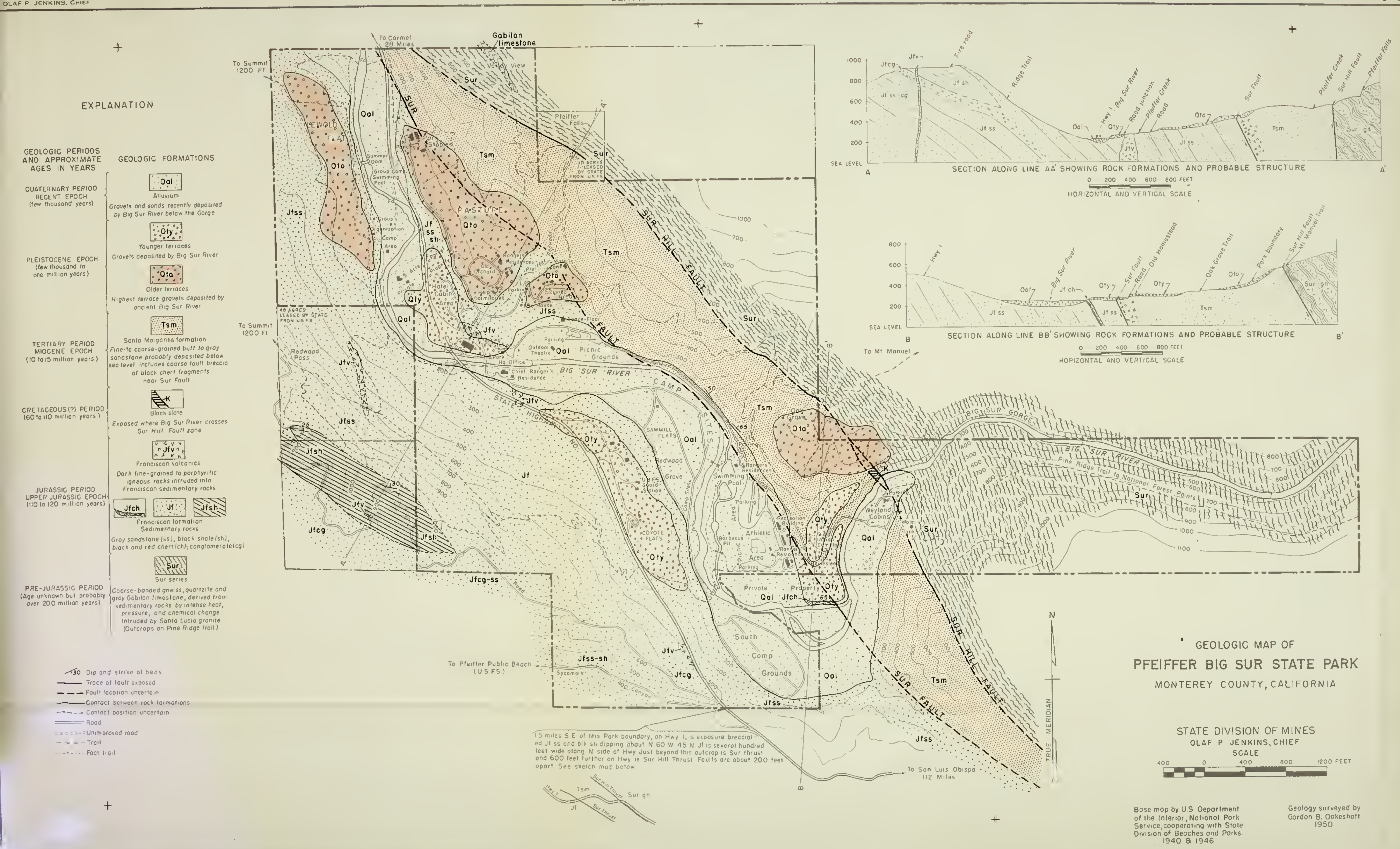


Figure 1. Index map showing general geology of the Monterey coast and location of Pfeiffer Big Sur State Park.


EXPLANATION
GEOLOGIC PERIODS AND APPROXIMATE AGES IN YEARS
GEOLOGIC FORMATIONS
QUATERNARY PERIOD RECENT EPOCH (few thousand years)
Qal
Alluvium
Gravels and sands recently deposited by Big Sur River below the Gorge
Qty
Younger terraces
PLEISTOCENE EPOCH (few thousand to one million years)
Gravels deposited by Big Sur River
Qto
Older terraces
Highest terrace gravels deposited by ancient Big Sur River
TERTIARY PERIOD MIOCENE EPOCH (10 to 15 million years)
Tsm
Santa Margarita formation
Fine-to coarse-grained buff to gray sandstone probably deposited below sea level. Includes coarse fault breccia of black chert fragments near Sur Fault
CRETACEOUS(?) PERIOD (60 to 110 million years)
K
Black slate
Exposed where Big Sur River crosses Sur Hill Fault zone
Jfv
Franciscan volcanics
Dark fine-grained to porphyritic igneous rocks intruded into Franciscan sedimentary rocks
JURASSIC PERIOD UPPER JURASSIC EPOCH (110 to 120 million years)
Jfch
Jf
Jfsh
Franciscan formation
Sedimentary rocks
Gray sandstone (ss), black shale (sh), black and red chert (ch); conglomerate (cg)
Sur
Sur series
PRE-JURASSIC PERIOD (Age unknown but probably over 200 million years)
Coarse-banded gneiss, quartzite and gray Gabilan limestone, derived from sedimentary rocks by intense heat, pressure, and chemical change. Intruded by Santa Lucia granite (Outcrops on Pine Ridge trail)
30 Dip and strike of beds
Trace of fault exposed
Fault location uncertain
Contact between rock formations
Contact position uncertain
Road
Unimproved road
Trail
Foot trail
To Carmel 28 Miles
Gabilan limestone
To Summit 1200 Ft
Valley View
Pfeiffer Falls
10 ACRES LEASED BY STATE FROM U S F S
EWOLD FLAT
PASTURE
Stables
Summer Dam
Group Camp Swimming Pool
Group Organization Camp Area
Rangers Residences
Old Orchard
Hotel Cabin Area
Help Dormitory
Lodge
Parking
Dance Floor
Outdoor Theatre
Picnic Grounds
Park Hq Office
Chief Ranger's Residence
BIG SUR RIVER
CAMP SITES
STATE HIGHWAY NO 1
SUR HILL FAULT
SUR FAULT
48 ACRES LEASED BY STATE FROM U S F S
To Summit 1200 Ft
Redwood Pass
SAWMILL FLATS
Redwood Grove
U S C S Guard Station
COYOTE FLATS
Swimming Pool
Rangers Residences
Recreation Building
Athletic Area
Barbecue Pit
Picnic Area
Parking
Oak Grove
BIG SUR GORGE
BIG SUR RIVER
Pine Ridge Trail to National Forest Points
Weyland Cabins
Water Tank
Homestead
Private Property
South Camp Grounds
To Pfeiffer Public Beach (U S F S)
Sycamore Canyon Road
To San Luis Obispo 112 Miles
To Mt Manuel
15 miles S E of this Park boundary, on Hwy 1, is exposure brecciated Jf ss and blk sh dipping about N 60 W 45 N. Jf is several hundred feet wide along N side of Hwy just beyond this outcrop is Sur thrust and 600 feet further on Hwy is Sur Hill Thrust. Faults are about 200 feet apart. See sketch map below
Hwy 1
Tsm
Sur Hill Thrust
Sur gn
Jf
Sur Thrust
SECTION ALONG LINE AA' SHOWING ROCK FORMATIONS AND PROBABLE STRUCTURE
0 200 400 600 800 FEET
HORIZONTAL AND VERTICAL SCALE
Fire road
Ridge Trail
Hwy 1 Big Sur River
Road Junction
Pfeiffer Creek Road
Sur Fault
Pfeiffer Creek
Sur Hill Fault
Pfeiffer Falls
SEA LEVEL
SECTION ALONG LINE BB' SHOWING ROCK FORMATIONS AND PROBABLE STRUCTURE
0 200 400 600 800 FEET
HORIZONTAL AND VERTICAL SCALE
Hwy 1
Big Sur River
Sur Fault Road
Old Homestead
Oak Grove Trail
Park boundary
Sur Hill Fault Mt Manuel Trail
N
TRUE MERIDIAN
GEOLOGIC MAP OF
PFEIFFER BIG SUR STATE PARK
MONTEREY COUNTY, CALIFORNIA
STATE DIVISION OF MINES
OLAF P JENKINS, CHIEF
SCALE
400 0 400 800 1200 FEET
Base map by U.S. Department of the Interior, National Park Service, cooperating with State Division of Beaches and Parks 1940 & 1946
Geology surveyed by Gordon B. Oakeshott 1950

Broad uplift, accompanied by some westward tilting, occurred late in the geologic history of the area, within the last half million years of the upper Pleistocene and Recent epochs. Each time such uplift took place the added grade increased the downcutting power of the Big Sur River and other streams and caused them to cut channels through their earlier gravel deposits, leaving the benches or terraces so well shown at Coyote Flats, in the Pasture and Park Stable area, and at the Old Homestead cabin. The number of successive levels of these terraces (five are recognized) is an indication of the number of periods of rest between periodic uplifts. The gentle slopes near the summit of Mount Manuel and elsewhere near the crest of the Santa Lucia Mountains are all that remain of the oldest erosion surface formed before the late succession of uplifts; the summit elevation (Mount Manuel 3,573 feet) is some suggestion of the total vertical amount of these movements. In a manner somewhat similar to the formation of the river terraces, wave action along the coast and periodic uplift have formed the coastal marine terraces. Steep-sided V-shaped canyons, like the Gorge, are evidence of the increased activity of downward erosion by the streams during and following uplift of the land.

Folding, caused by severe compressive forces within the earth's crust, is best seen in stratified (layered) rocks which must have been deposited in nearly horizontal layers as mud, sand, and gravel. The dark well-stratified shale and sandstone of the Franciscan formation exposed, for example, along the Fire Road southeast of Redwood Pass clearly have been folded. Such folding must have taken place *after* the shales and sandstones were deposited and *before* the flat-lying gravels of the oldest terrace were deposited.

Faulting has been a major form of crustal activity in the Big Sur area and has left its imprint in the landscape. Two faults—Sur and Sur Hill—trend northwestward through the Park. Where directly exposed by road cuts or by stream erosion as, for example, 200 feet down Pfeiffer Redwood Creek from Pfeiffer Falls, on the right bank of the Big Sur River below the Gorge, and on Highway 1 south of the Park, movement along the fault has crushed, broken, and powdered the rocks in zones several feet wide, producing the coarse fragmented rock called "fault breccia" and the finer clay-like crushed rock called "gouge." Fault breccia and gouge weather and erode more easily than fresh rock and consequently benches on slopes, saddles, slumps, and slides are common along fault zones. The northwesterly course of the Big Sur River through the Park has probably been controlled by the Sur fault. To a geologist, the best evidence of all that faulting has taken place is the finding of two adjacent rock formations that have been displaced so as to place them in the wrong position. For example, the Sur gneiss, which is probably hundreds of millions of years old, must originally have lain far below the Santa Margarita sandstone which was deposited in a sea only a few million years ago. Now the Sur gneiss is found thousands of feet higher where it has been thrust up and over the Santa Margarita formation along the Sur Hill fault.

In studying the geologic history of a region such as Big Sur State Park, the geologist must recognize the various kinds of rocks and their modes of origin, he must map their position and distribution, he must note on the map their attitude (inclination, direction, form), he must recognize and plot faults and he must study the landscape for what surface expression he can find of buried geologic features. By such observations and the application of geologic reasoning, the long story of the formation and development of the land forms may be partly deciphered.

Previous Geological Work. Comparatively little previous geological work has been done on the Big Sur area, but in 1926 Trask [1] discussed the geology of an area of about 150 square miles in the Point Sur quadrangle. He published a colored geologic map on the scale of 1 inch equals 1 mile. An area of similar size, the Lucia quadrangle just southeast of Point Sur quadrangle, was described by Reiche in 1937.[2] The State Geologic Map, published by the Division of Mines in 1938, shows the general geology of the entire state, including the Big Sur area, on the scale of 1 inch equals 8 miles.[3]

In the present study, undertaken by the Division of Mines, field mapping was done on the scale of 1 inch equals 400 feet. The work of Trask was used as the basic reference.

GEOLOGY

Pfeiffer Big Sur State Park is an area of a little over 1 square mile along the lower course of the Big Sur River about 30 miles south of Monterey. State Highway 1 crosses the park area and in its roadcuts has exposed some of the geologic features. The park area is very close to the west coastal margin of the Santa Lucia Mountains, a part of the northwest-trending Coast Ranges. The Santa Lucia Mountains reach an elevation of several thousand feet and, in general, are marked by rather gently sloping rounded summit areas in which deep canyons have been cut by the eroding streams. The west slope of the range is extremely rugged and drops off abruptly to steep cliffs along the margin of the ocean.

The central part of the Santa Lucia Mountains is made up of the old crystalline, intensely altered and metamorphosed rocks of the Sur series, which have been intruded in many places by the granitic rocks of the Santa Lucia group. Along the western margin of the range is a great series of thrust faults along which various slices of rock formations have been thrust upward and over formations which lie to the west. Involved in the thrust zone are rocks of the Sur series, the Santa Lucia granite, Franciscan formation sedimentary rocks, and remnants of Cretaceous, Miocene, and still younger sedimentary formations, for the most part sandstones, shales, and cherts. Late in the history of formation of the Santa Lucia Mountains, the range was elevated by at least 3000 feet and tilted westward along faults which follow the east boundary of the mountains. The amount of uplift lessened to the west, but amounted to several hundred feet along the coast, as is shown by the numerous marine terraces at several levels, which have been eroded by marginal west-flowing streams and by wave action to form the rugged coastal cliffs that characterize the region today.

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[1] Trask, Parker D., Geology of Point Sur Quadrangle, California: Univ. Calif., Dept. Geol. Sci., Bull., vol. 16, pp. 119-186, 1926.

[2] Reiche, Parry, Geology of the Lucia Quadrangle, California: Univ. Calif., Dept. Geol. Sci., Bull., vol. 24, pp. 115-168, 1937.

[3] Jenkins, Olaf P., and others, Geologic map of California: Calif. Div. Mines, 1938.

FIGURE 2. Panorama from Highway 1 across Big Sur valley from northwest to southeast. Sur fault follows the base of the mountains close to the course of the Big Sur River as indicated by tree cover at the lowest elevation. Sur Hill fault follows approximately the bench near the base of the steepening slope changes above the valley floor. Buildings at lower left are on one of the older, higher terrace deposits left by the ancient Big Sur River. Note precipitous lower slopes and the geologically older, more subdued relief at higher elevations. Mount Manuel is the highest peak shown. *Photography, Charles W. Chesterman.*

FIGURE 3. View eastward up Big Sur Gorge from Pine Ridge trail. Extremely steep canyon sides have been developed by the Big Sur River, cutting its valley through resistant rocks of the Sur series. *Photography, Charles W. Chesterman.*

FIGURE 4. View from Redwood Pass north across Big Sur valley toward Mount Manuel. Building at lower right is on older terrace. Sur Hill fault passes from left to right approximately across the back, higher part of the terrace bench. Above the Sur Hill fault the rock formation exposed is Sur series gneiss; lighter colored outcrops include Gabilan limestone lenses. *Photography, Charles W. Chesterman.*

Rock Formations in the Park

Sur Series Gneiss and Santa Lucia Granite. The Sur series gneiss is the oldest rock formation in the area. It is exposed in the park area just northeast of the Sur Hill fault, where gneiss has been thrust upward to the west over all younger formations. In the Park area the Sur gneiss has been thrust directly over the Santa Margarita sandstone. The Sur gneiss consists of a group of very ancient complexly banded, coarse-grained to fine-grained rocks resulting from the intense metamorphism (brought about by the heat, pressure, and chemical activity of mountain building) of what must have been at one time a thick series of sedimentary rocks, such as sandstone, conglomerate, limestone, and shale. Metamorphism of the coarser-grained rocks has formed the coarsely banded gneisses, and the finer-grained rocks now appear as schist, particularly mica schist and quartzite. Limestone was generally recrystallized to form the grayish, more or less coarsely crystalline lenses of limestone, such as that cropping out at Valley View northwest of Pfeiffer Falls. The limestone has been named the Gabilan limestone. Its outcrops are readily recognized in contrast to the darker banded gneisses. Although the Sur series gneiss and schist crop out very extensively through the higher parts of the Santa Lucia Mountains, they may be best seen and studied in the Park area through the gorge of the Big Sur River and along the Pine Ridge trail, which gives fine exposures of the Sur gneiss and a marvelous view of the steep narrow gorge which the Big Sur River has cut in this resistant rock formation. Locally, the Sur gneiss has been intruded by the granitic rocks, later in age, named the Santa Lucia granite by early-day geologists. The ages of the Sur series gneiss and the intruding Santa Lucia granite are unknown, but geologists do know that they are the oldest formations in the area and have some evidence for believing that they are older than the Mesozoic era, that is, over 200 million years in age.

Franciscan Formation. In general, the complex rocks of the Franciscan formation crop out west and southwest of the Sur fault in the Park area. They are very widely exposed wherever highway roadcuts have been made and where the streams have undercut their banks. The Franciscan formation is one that is distributed throughout the Coast Ranges of California. It is quite typically exposed in the Big Sur area. It consists primarily of a group of sedimentary rocks of a probable thickness of several thousand feet, consisting particularly of a greenish-gray to black, medium to fine-grained sandstone with thin interbeds of black shale. Here and there are lenses of hard, microscopically-grained chert, sometimes black, green, or red. The formations are probably largely marine in origin. No fossils have yet been found in the Big Sur area.

Volcanic rocks are quite common in the Franciscan, and crop out in a few spots in the Park area. The most accessible outcrops of the Franciscan volcanics are just to the north across the road from the checking station at the entrance to the Park; another is about 800 feet southeast of that spot exposed in a big roadcut on Highway 1. The rock weathers to a light brown color and is fine-grained, containing easily distinguishable white laths of feldspar in the fine-grained groundmass (matrix). It was probably not thrown out of a volcano in explosive action, but instead was intruded as molten "lava" into the sandstones of the Franciscan formation. It might even be later than Upper Jurassic in age. Microscopic study of a thin section (transparent slice 0.03 millimeter thick) of this rock shows that it is a very unusual type in California related to keratophyre. The microscope reveals numerous long slim laths of white albite feldspar and less numerous laths of a pyroxene (?) mineral irregularly distributed in a groundmass consisting of a felted mat of these same minerals with interstitial grains of biotite mica and chlorite. Before becoming altered and weathered, the rock was probably composed of about 75 percent albite feldspar, with the balance chiefly brown biotite mica and a dark pyroxene mineral.

Black chert, interbedded with the Franciscan sandstone and shale, may be best seen just west of the Sur fault on the north side of the big loop in the Big Sur River about 400 feet due south of the Old Homestead cabin. The black chert has been broken, fractured and brecciated along the Sur fault zone and, as this area was being eroded in early Santa Margarita time, black chert fragments were picked up and deposited along with the Santa Margarita sands and appear today in the lower part of the Santa Margarita sandstone formation within a few feet of the Sur fault. In general, the rocks of the Franciscan formation have been tilted toward the northeast at angles from about 25 to over 50 degrees. Most of this tilting probably occurred about the same time as the major movements along the Sur Hill and Sur fault zones.

The age of the Franciscan formation elsewhere in California has been considered as Upper Jurassic, or about 110 to 120 million years. Some of the sediments of the Franciscan were probably derived from the erosion of the Sur gneiss and Santa Lucia granite, which lay to the east of the Franciscan seas, but some may also have come from a landmass that lay to the west, which has long since subsided beneath the ocean.

Cretaceous (?) Rocks. About 20 feet of dark black shale is exposed along the Sur Hill fault where it crosses the Oak Grove Trail. A slightly harder black slate is exposed in the same fault zone on the northwest bank of the Big Sur River. This black shale or slate is of questionable Cretaceous age and represents simply a remnant of old Cretaceous sedimentary rocks caught up and overridden by Sur gneiss in the zone of the Sur Hill fault.

Santa Margarita Formation. The Santa Margarita formation crops out in the Big Sur area only in the narrow zone between the Sur fault and the Sur Hill fault. It represents a remnant of a once more extensive sandstone, which was over-ridden on the east by the Sur gneiss along the Sur Hill fault and was itself pushed upward and westward over the Franciscan rocks along the Sur fault. For the most part, the Santa Margarita sandstone varies from a fine-grained brown sandstone to a coarse-grained white pebbly sandstone with a little conglomerate. It is essentially massive, that is, it is difficult to distinguish any sign of bedding or stratification, although the formation was probably tilted to the northeast, as was the Franciscan formation, when the major faulting occurred. The most distinctive feature of the Santa Margarita formation in the Big Sur area is the breccia made up of sandstone and black Franciscan chert, fragments of which are found in the lower part of the Santa Margarita formation along the Sur fault zone. It was the result of erosion

FIGURE 5. View from Redwood Pass east southeast. Wooded area at low elevation near center of picture is in the loop of the Big Sur River a few hundred feet below the Gorge. The old, mature erosion surface of the uplands is in sharp contrast to the steep lower slopes. The prominent bench on these lower slopes marks the trace of the Sur Hill fault. *Photography, Charles W. Chesterman.*

FIGURE 6. View from Highway 1 across Coyote Flats directly down Big Sur valley toward the northwest. *Photography, Charles W. Chesterman.*

FIGURE 7. Sur fault zone on Highway 1, about 1.6 miles southeast of Park boundary. Oak trees near center of photograph are located in the brecciated, broken, and weathered rock on the Sur fault. Franciscan sandstone and shale crop out in the highway cut to the extreme left, while light outcrops of Santa Margarita sandstone appear on the extreme right. *Photography, Charles W. Chesterman.*

FIGURE 8. View northwest along Sur Hill fault from Pine Ridge trail. The trace of the fault follows along the up-slope side of the prominent bench, which may be traced near the center of the picture away from the viewer. The prominent bench with the reservoir building at left center represents the highest (oldest) deposit of terrace gravels left by the ancient Big Sur River. *Photography, Charles W. Chesterman.*

FIGURE 9. Slump zone along Sur Hill fault, northwest side of Big Sur Gorge. *Photography, Leonard B. Penhale.*

while first movements along the Sur fault were taking place. The Franciscan rocks were intensely broken and fractured to form a breccia made up of angular particles of Franciscan rock, including some sandstone, but particularly the hard, dense, black, resistant chert. The black-chert breccia is most strikingly exposed along the west bank of Pfeiffer Creek just north of the Sur fault, and in steep cliffs about opposite the junction of the Oak Grove Trail and the Pfeiffer Creek Trail. It is also well exposed in steep cliffs along the road at the Sawmill Flat Camp Ground, where the Sur River has for thousands of years been undercutting its right bank to form a series of steep slopes near the trace of the Sur fault. Good outcrops of the Santa Margarita sandstone may also be seen in the roadcuts at the foot of the terrace near the Old Homestead cabin and along the nearby portion of the Sur River. The formation of this breccia is evidence that movement along the Sur Hill fault began in early Santa Margarita time, that is, toward the close of the Miocene epoch, possibly ten million years ago.

Terrace Gravels and Alluvium. The present Big Sur River rushes at steep grade through the hard, resistant crystalline rocks of the Sur series to form the narrow rock-bound valley called the Gorge, in the eastern part of the Park. As it emerges from the lower end of the Gorge, its velocity is slowed and it has built up a series of boulders, gravel, and sand deposits along a channel several hundred feet wide. These stream-deposited sands, gravels and boulders make up the alluvium outlined on the geologic map along the course of the Big Sur River. Older gravels, sands, and boulders formed in a similar way by deposition from the Big Sur River, occur as benches or terraces up to 300 feet above the present stream level. They represent an older, higher course of the Big Sur River and were formed prior to the most recent uplifts, which caused the river to cut deeper in its channel. The oldest of these terrace gravels, maybe early Pleistocene in age (possibly up to one million years old), suggests that the Sur River at one time ran westward from the present Gorge area along the Sur fault and Sur Hill fault zones. Later uplift and westward tilting have caused the Big Sur River to cut deeper in its channel and, in general, to shift toward the southwest leaving its gravel deposits behind it. This feature may be particularly well observed in the terraces just north of the main bend in the Big Sur River after it emerges from the Gorge.

FIGURE 10. Big Sur River flowing over low grade through alders in the camp area. *Photography, Leonard B. Penhale.*

FIGURE 11. Slide area on Highway 1 opposite Group Organization Camp. The rock is dark Franciscan shale with some dark gray sandstone beds. This formation when water saturated very commonly is responsible for major slides, especially where the slopes are steepened in highway cuts. The light outcrop near left top of slide slope is a remnant of older terrace gravels left by the Big Sur River. *Photography, Charles W. Chesterman.*

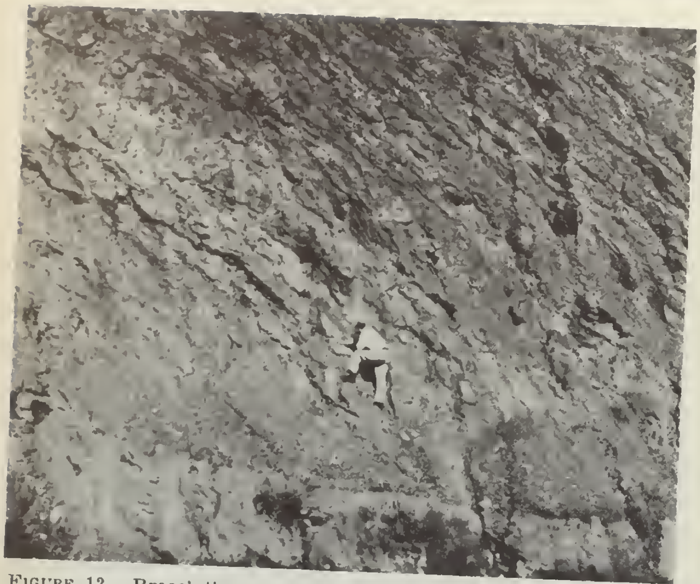

Figure 12. Brecciation and gouge developed in Franciscan sandstone and shale adjacent to Sur fault on Highway 1 about 1.5 miles south of Park boundary. The prominent stratification dipping toward the right (northeast) indicates stratification of these sandstone and shale beds, and is also approximately the attitude of the Sur fault which passes across the highway a few feet to the right. *Photography, Charles W. Chesterman.*

Structural Features

The dominant structural trend of the area is west of north, consistent with the general structural trend of the Coast Ranges and the Santa Lucia Mountains. The main structural features of the region are the thrust faults—the Sur Hill fault and the Sur fault—along which the rock formations were thrust several thousand feet upward and over both younger and older formations, with the movements in a general southwesterly direction. The whole group of formations, including the Sur gneiss, the Franciscan formation, and Santa Margarita formation has been tilted at angles of 30 to more than 60 degrees toward the northeast, in conformity with the general movement along these great faults. Actually, the structural trend of the region is oblique to the general west-of-north trend of the Santa Lucia Mountains, with the local structures tending a little bit more westward, so that the fault zone intersects the coastline a few miles north of Big Sur. Age of the faulting can not be fixed with certainty, but the fact that fault breccias were forming along the Sur Hill fault in early Santa Margarita time suggests strongly that fault movements were taking place as early as upper Miocene time. The fact that the Pleistocene terrace and bench gravels left by the old Big Sur River were not cut or displaced by the faults, but rather were deposited across the fault traces, indicates that movements along the Sur Hill fault and Sur fault probably ceased by the early Pleistocene epoch. Since the faulting, there has been a series of uplifts of the mountain block with a general tilting toward the west.

Summary of Geologic History

The geologic history of any region must be reconstructed from a study of the exposed rock formations, the structural arrangement of such rock formations, and the land surface, or topographic features of the region. A consideration of all these things makes possible some reconstruction of the major events in the local earth

Figure 13. Pfeiffer Falls. The water is flowing down a steep, eroded surface of Sur gneiss. The falls were developed thousands of years ago as Pfeiffer Creek cut its course over Sur gneiss and encountered less resistant Santa Margarita sandstone at the Sur Hill fault. Erosion has since caused the falls to retreat upstream from their original location approximately 200 feet horizontally. *Photography, Leonard B. Penhale.*

Figure 14. Terrace gravels lying on white Santa Margarita sandstone; the pick marks the contact. Old Homestead cabin at top. *Photography, Charles W. Chesterman.*

Figure 15. Gravels being deposited by Big Sur River about 1500 feet below the Gorge. The pebbles and boulders consist chiefly of Sur gneiss and Santa Lucia granite which have been eroded from the Gorge area and dropped·by the stream as it came to lower grade. *Photography, Charles W. Chesterman.*

Figure 16. Cretaceous conglomerate exposed on Highway 1 near Hot Springs Creek a few miles south of the Park. This is a hard, firmly cemented conglomerate which suggests the type of solid rock that might be formed if the gravels seen in figure 16 were to be buried by later sediments and cemented over a long period of geologic time. *Photography by Charles W. Chesterman.*

Figure 17. View north toward Big Sur Gorge across dry abandoned channel of Big Sur River just east of South Camp Grounds. Note the most recent of the terrace deposits appearing a few feet above the channel level as a light colored, gently sloping surface seen through the trees. *Photography, Charles W. Chesterman.*

Figure 18. Mouth of Big Sur Gorge. The valley here is narrow with extremely precipitous side slopes. The huge fragments of Sur gneiss which lie in river bed have fallen from the steep slopes and have been moved a very short distance downstream during flood periods of the river. *Photography, Charles W. Chesterman.*

history, from what we see today in the rock formations structures and land forms of the Big Sur area.

More than 200,000,000 years ago in pre-Mesozoic time, a great thickness of sedimentary rocks was accumulated, probably largely below sea level, later to become the Sur series gneiss. This early Sur series was intruded by molten rock, which crystallized to form the Santa Lucia granite far below the surface of the earth.

After a gap in the known record of something like 100,000,000 years, the next major event in the history of the region was the formation of a long trough in which the marine sedimentary rocks of the Franciscan formation were deposited. This trough was not local in the

FIGURE 19. Vertically-banded Sur series gneiss near mouth of Big Sur Gorge. This rock was probably deposited as a sediment in a nearly flat attitude in early geologic time, and has since been turned on edge and intensely altered by heat and pressure (metamorphosed) in mountain building. *Photography, Charles W. Chesterman.*

FIGURE 20. Dark gray-black shale of the Franciscan formation exposed on Fire Road southeast of Redwood Pass. *Photography, Charles W. Chesterman.*

FIGURE 21. Massive Franciscan conglomerate exposed on Fire Road southeast of Redwood Pass. This conglomerate lies just below the shale beds noted in figure 20. *Photography, Charles W. Chesterman.*

FIGURE 22. Black-chert breccia in Santa Margarita sandstone in roadcut at Sawmill Flat. Notice the extreme irregularity in the distribution of the black-chert fragments distributed through the coarse, light gray sandstone. This outcrop is just a few feet north of the probable trace of the Sur fault zone, which here follows the right bank of the river. *Photography, Charles W. Chesterman.*

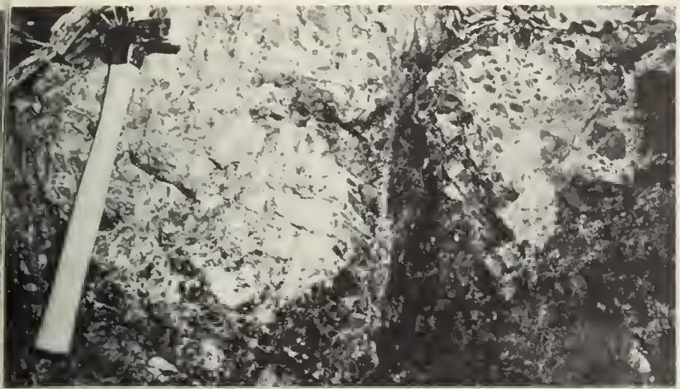

Figure 23. Coarse black-chert breccia in Santa Margarita sandstone at Sur fault on Pfeiffer Redwood Creek. *Photography, Charles W. Chesterman.*

Figure 24. Chert breccia in Santa Margarita sandstone north of Sur fault on Pfeiffer Redwood Creek. *Photography, Charles W. Chesterman.*

Big Sur area, but extended in general through the entire Coast Range of California. Sediments formed by erosion of mountainous areas to the east, and possibly some western lands also, were deposited in a sinking trough to form the sands, muds and cherts of the Franciscan formation. Intermittent volcanic activity took place, some of it probably below sea level. Marine formations of Cretaceous age are evidence that the area was also a seaway in part of Cretaceous time.

In the early part of the Tertiary period, that is, in the Eocene-Oligocene epochs, the Big Sur area was probably above sea level as no sedimentary rocks of these ages are known. The seas advanced in early and middle Miocene time, and then in upper Miocene time (Santa Margarita) the area was locally elevated. Part of the uplift of the land mass formed may have been along the Sur fault zone, which probably came into being during upper Miocene time. As the land mass was elevated, rapid erosion formed the sandy deposits of the Santa Margarita formation in the margin of the sea to the west. The upper Miocene seas, and probably also Pliocene seas, must have extended from the Pacific area several miles east of the present coastline, with a shoreline possibly east of the present Sur Hill fault in the Park area.

Thrust faulting continued and was sharply renewed toward the close of the Pliocene epoch and into early Pleistocene time. Following thrust faulting a series of more or less vertical uplifts of the whole Santa Lucia block began, which brought the main part of the range upward by as much as 3000 to 5000 feet during Pleistocene and Recent times. Westward tilting occurred along with the regional uplift. Evidence of a succession of late Pleistocene to Recent uplifts is found in the numerous marine terraces along the present coast, in river terraces like those in the Park area left by the ancient Big Sur River, and by the deep narrow valleys cut by west-flowing streams.

Figure 25. Photomicrograph of thin section of porphyritic volcanic rock which intrudes Franciscan sandstone on Highway 1 near Chief Ranger's residence. X-nicols. 70x. Long slim phenocrysts of albite feldspar in groundmass of albite and interstitial altered biotite and pyroxene.

Figure 26. Photomicrograph of thin section of porphyritic volcanic rock which intrudes Franciscan sandstone on Highway 1 near Chief Ranger's residence. X-nicols. 70x. Longest white phenocryst is pyroxene which has been completely replaced by calcite (white) and chlorite (dark patches); the smaller phenocryst is albite feldspar. The groundmass is principally albite, with interstitial altered biotite and pyroxene.

AGE	FORMATION	ROCK TYPE	DESCRIPTION
Quaternary: Recent (Age: a few thousand years)	Alluvium		Gravels and sands recently deposited by Big Sur River.
	Younger terrace		Bench and terrace gravels deposited by ancient Big Sur River.
Pleistocene (Age: a few thousand to 1 million years)	Older terrace		Oldest (highest) bench or terrace gravels left in earliest stages of river deposition.
Tertiary: Miocene (Age: 10 to 15 million years)	Santa Margarita		Fine- to coarse-grained buff to gray sandstone, probably deposited below sea level; very coarse black chert breccia near Sur Fault zone.
Cretaceous (?) (Age: 60 to 110 million years)			Black slate of uncertain age exposed as slivers in Sur Hill fault zone.
Jurassic: Upper (Age: 110 to 120 million years)	Franciscan		Dark gray to black sandstone, conglomerate, and interbedded shale; thin lenses of black and red chert. Intruded by small irregular bodies of porphyritic "volcanic" rock.
Pre-Mesozoic (Age: unknown, but probably over 200 million years)	Santa Lucia granite Sur Series gneiss		Coarse-banded gneiss, quartzite, and gray Gabilan limestone beds or lenses; derived from sedimentary rocks by intense heat, pressure, and chemical changes brought about by mountain building. Intruded by Santa Lucia granite.

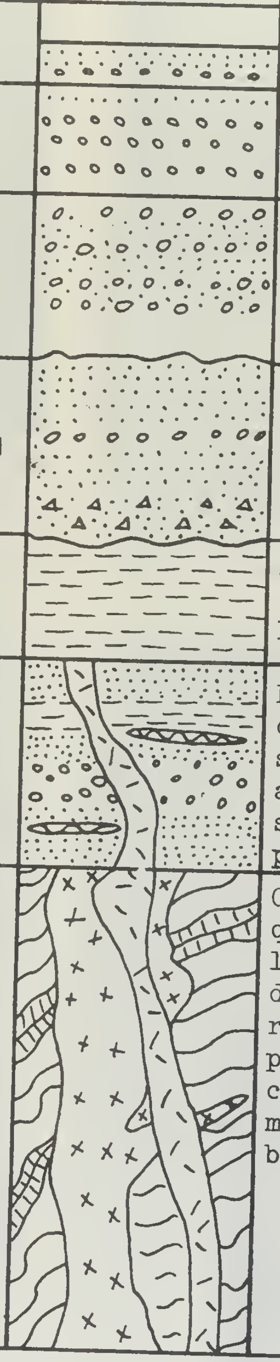

Figure 27. Stratigraphic column showing rock formations in Pfeiffer Big Sur State Park.

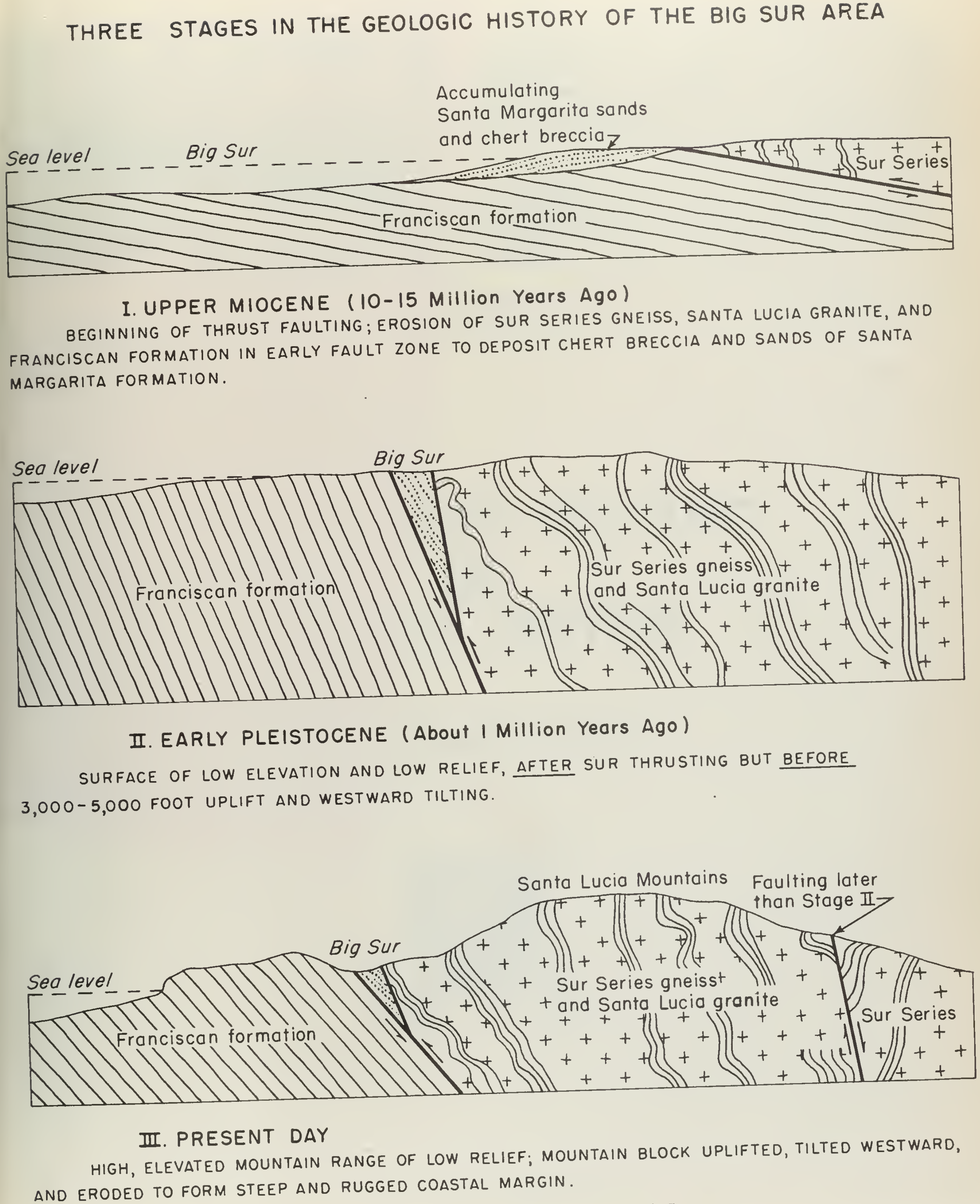

Figure 28. Three stages in the geologic history of the Big Sur area.

Present features of the land surface, as seen in the Park today, are therefore the result of geologically late processes of uplift and erosion by running water. The Big Sur River must have started as a westward-flowing stream down the tilted rising slope of the Santa Lucia Mountains, possibly in early Pleistocene time. As further uplift and tilting took place, and as the Sur fault and Sur Hill fault movements occurred, the Sur River incised itself in the crystalline rocks of the Sur series to form the deep rugged Gorge and cut its way along the more easily eroded brecciated rock in the thrust fault zones toward the northwest. With continued Recent uplift and westward tilting, the stream has had a tendency to slip off toward the southwest, forming, for example, the major loop in the Park area just below the Gorge. The present stream is exerting most of its energy in rapid down-cutting over its steeper gradient in the resistant crystalline rocks of the Sur series and in side-cutting and undermining its banks on the outside of its loops through the relatively flat valley of the Park area. In the next few thousand years, unless some unforeseen geologic interruptions occur, it can be expected that the Big Sur River will lower its grade and widen its channel slightly in the Gorge area, and in the valley below will widen that valley at about its present level, by undercutting its banks to the south in the area of the South Camp Grounds, to the north in the area of Sawmill Flats, and to the northwest in the area northwest of the Lodge.

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